Investigating Semantic Priming in Adulthood:

Differential Contribution of Subtypes of Thematic Relatedness

Research Thesis

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by

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Abstract

There are at least two types of semantic relations important for understanding cognitive development: taxonomic and thematic relations. Until recently, the literature focused primarily on the importance of taxonomic relations, or relations based on shared features (DOG – CAT), as it was believed that thematic relations (DOG – LEASH) only play a dominant role early in childhood (e.g. Inhelder & Piaget, 1964; Smiley and Brown, 1979). The lack of investigation has led to inconsistencies in defining thematic relations among researchers. The goal of the present study was to compare the effects of different types of thematic relations within the same experimental paradigm. We employed a lexical decision task in adults to compare priming effects of four types of thematic relations: attributive (FLY - WINGS), argument (BEAR - FISH), coordinate (CHAIR – TABLE), and locative (BEAR – FOREST) (Jouravlev, & McRae). We found significant priming effects for coordinate and locative relations. However, there were no priming effects for attributive and argument relations. Our results call for the further investigation of thematic relations and have the potential to further our understanding of the nature of thematic relatedness.

Introduction

Understanding the organization of semantic memory is vital to understanding human cognition. Semantic relations are essential as they guide our behavior and allow us to understand how items in the world will interact with one another (McRae & Jones, 2013; Tulving, 1972; Yee, Chrysikou, & Thompson-Schill, 2015). For an extended period, researchers focused on one type of semantic relation: taxonomic relations (for a review see Murphy, 2002). A taxonomic relation is defined as a similarity based on shared features (Jackson, Hoffman, Pobric, & Ralph, 2015). The objects *dog* and *cat*, for example, share a taxonomic relation as both have fur, four legs, and are common household pets. Taxonomic relations have been regarded as the dominant mode of

sematic organization and therefore have been studied much more in depth compared to other types of semantic relations (for a discussion see, Murphy, 2002; Estes, Golonka, & Jouravlev, 2011; Mirman & Graziano, 2012).

Recently, however, researchers have begun investing more efforts to understand the importance of another semantic relation known as a thematic relation. A thematic relation can be defined as any temporal, spatial, causal, or functional relation between items (e.g DOG – LEASH) (Estes, Golonka, & Jouravlev, 2011). For decades, thematic relations were thought to be significant only in early childhood (Vygotsky, 1962; Inhelder & Piaget, 1964; Smiley and Brown, 1979), allowing taxonomic relations to take precedence in the scientific world. Within the last decade, however, there has been an accumulation of evidence showing the importance of thematic relations in both childhood and adulthood (Lin & Murphy, 2001; Mirman & Graziano, 2012; Savic, Savic, & Kovic, 2017). Despite the recent interest in thematic relatedness, researchers continue to disagree on the definition of the relation. Some, for example, emphasize the role of temporal implication or the co-occurrence between items (e.g. Landrigan & Mirman, 2017; Lin & Murphy, 2001). Others emphasize that in addition to co-occurrence, items also need to play complementary roles, i.e. interact with one another (Estes, Golonka, & Jouravlev, 2011; Jouravlev & McRae, 2015). Thus, based on an explanation given by Estes, Golonka & Jouravlev (2011), hammer and nail are thematically related not only because they co-occur, but because they have features allowing them to interact; a hammer is able to be held and used to hit, while a nail has a flat head creating a surface to be hit upon. While the role of interaction is plausible, the importance of this aspect of thematic relatedness has not been empirically tested thus far.

Due to the lack of clarity in defining thematic relatedness, much of previous research neglected the differential influence types of thematic relations may potentially have in the

organization of semantic memory. One of the rare studies that contrasted different types of thematic relations was a study by Moss and colleagues (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995), where they found stronger evidence for priming of what they defined as instrument relations (BROOM - FLOOR), compared to script relations (RESTAUANT - WINE). Here we ask whether or not different types of thematic relations play different roles in the organization of semantic memory is an important question, as it may further our understanding of the nature of thematic relations and offer a potential explanation for the inconsistent findings in the literature.

In addition to the issue of defining thematic relatedness, it is also important to understand how we can measure this type of semantic relatedness. The most common practice in the literature was that authors, themselves, would select several items, guided by one of their definitions, and validate strength of thematic relatedness for the selected sample based on human judgments. There have been efforts in recent years to improve this practice. For example, Mirman and Landrigan created a database of human judgments for 659-word pairs from data collected by a group of independent researchers (Landrigan & Mirman, 2016). Some have taken this a step further, following the approach commonly used to estimate associative relatedness strength. In a study by Jouravlev and McRae (2015), 200 participants were asked to read a word and then respond with a thematically related word. Responses that were not thematically related were excluded from further analyses. In the following step, they recruited an additional 500 participants that sorted pairs of words into five types, identified in prior research: attributive, argument, coordinate, locative, and temporal (Borghi & Caramelli, 2003; Estes, Golonka, & Jouravlev, 2011). An attributive relation was defined by Jouravlev and McRae (2015) as a relation between an object and a characteristic of itself (e.g. BAKER - APRON). Argument relations occur between an object that performs an action that changes the state of another object (e.g., BEAR - FISH). Coordinate

relations occur between two objects that are a part of the same event but do not interact with each other (e.g., BEER - CHIPS). Locative relations occur between an object and its typical location (e.g., DOCTOR - HOSPITAL). Finally, temporal relations occur between an object and a time (e.g., CHURCH - SUNDAY) (Jouravlev & McRae, 2015). Although these norms offer an interesting new approach to measuring thematic relatedness, it is still unclear whether the classification offered by Jouravlev and McRae (2015) are cognitively valid.

The goal of the present study is to investigate how different types of thematic relations affect cognitive processing. The study had two main aims. Our first aim was to investigate whether thematic priming is dependent on the potential for the interaction between the items, as it has been previously suggested (Estes, Golonka & Jouravlev, 2011). If interaction is an important part of thematic relatedness, then we would expect that items that more frequently interact show stronger priming effects than items that rarely interact. The second goal was to examine differences in priming effects across four types of thematic relatedness as identified by Jouravlev and McRae (2015).

Study 1: Stimuli norming

The goal of Study 1 was to estimate potential for interaction between the thematically related pairs selected from the thematic production norms provided by Jouravlev and McRae (2015).

Participants

28 participants took part in an online norming study. All participants provided informed consent prior to their participation.

Stimuli

The stimuli were pairs of thematically related words selected based on the norms by Jouravlev and McRae (2015). We selected the word pairs based on the strength of thematic relatedness as reported by Jouravlev and McRae (2015). Since the word pairs that were most strongly related varied greatly on measures of thematic relatedness and other relevant dimensions (e.g. frequency, thematic type), we selected the pairs that were within the third quartile based on the thematic relatedness strength. There was a total of 60-word pairs selected for the study with 15 pairs from each of the four types of thematic relatedness (argument, attributive, coordinate, locative).

Procedure

Participants took part in an online norming study created using Qualtrics online survey platform. They were presented with word pairs and asked to rate how likely the items denoted by words are to interact. We used a 7-point scale, anchored from one (no interaction) to 7 (high interaction). Objects were said to interact if "they are often found together and have an effect on each other."

Results

We first calculated the mean interaction potential for each of the rated word pairs. Further, for the same set of stimuli pairs, we collected information about the thematic relatedness from the study of Jouravlev and McRae (2015) and associative relatedness (Forward Association Strength) from the Florida Free Association norms (Nelson, McEvoy, & Schreiber,1998).

For each of the three measures of relatedness (interaction, associative strength and thematic strength) between the related word pairs we conducted a one-way ANOVA with Thematic Type (Argument, Attributive, Coordinate, Locative) as the factor. Our analyses confirmed that there

were no differences in strength of thematic relatedness between the four Thematic Types ($p > .10$). On the other hand, there was a significant difference in strength of associative relatedness *(F* (3,41) = 14.45, $p < .01$, $\eta = .53$). As confirmed by Bonferroni post-hoc comparisons, Coordinate type (BEER – CHIPS) was more strongly associated than all three other types ($p < .01$), which were not significantly different from each other. Our analyses again confirmed that there was a significant difference in strength for interaction potential (F (3,59) = 2.888, $p < .05$, $\eta = .134$). Confirmed by Bonferroni post-hoc comparisons, Coordinate type showed marginally higher potential for interaction more than the other three groups ($p = .1$). Table 1 shows the mean values of three kinds of relatedness across the four Thematic Types.

Table 1

Mean values for three measures of relatedness across four Thematic Types (standard deviations are in parentheses)

	Argument	Attributive	Coordinate	Locative
Thematic	64.27 (13.60)	60.27 (11.52)	74.13 (26.61)	64.67 (10.99)
Associative	.07 (.05)	.04 (.03)	.36 (.24)	.05 (.05)
Interaction Potential	5.05 (1.06)	4.42 (.57)	4.23 (.94)	4.89 (.87)

Notes: Mean Standard deviation

Discussion

The purpose of this study was to examine if the four Thematic Types (argument, attributive, coordinate, locative) were comparable across three types of relatedness. As the Coordinate type was significantly different than the three other types on associative relatedness and interaction potential, we examined potential correlations in our second study

Study 2

Participants

Forty-two participants took part in the present study. Participants were undergraduate students at The Ohio State University. All participants provided an informed consent form prior to their participation. Nineteen additional individuals were excluded. (11 due to low accuracy, 7 inability to understand task and 1 for incompletion of the study).

Stimuli

A list of 120 words and 120 pseudowords were used in this study. The same list of words from study 1 were selected based on thematic production norms developed by Jouravlev and McRae (2015). Related word pairs were divided evenly into four thematically related types (argument, attributive, coordinate, and locative) (Jouravlev & McRae, 2015). Based on the list of 60 thematically related prime – target pairs, we further developed the list of unrelated pairs. We used the same set of targets and primes that were used to make related pairs, but randomly paired them to produce the unrelated pairs.

Pseudowords were constructed using the pseudoword generator, Wuggy (Keuleers & Brysbaert, 2010). With an algorithm constructed by Wuggy creators, we used target words from the current study to generate pseudowords in English. As the pseudowords were generated from the current study, they were comparable on word length, structure, and number of syllables. See ***Table 2*** for example of stimuli.

Table 2
Example of stimuli pairs

Prime	Target	Condition	Lexicality
chicken	egg	related	word
circus	egg	unrelated	word
chicken	etd	unrelated	nonword

Procedure

Participants completed a standard lexical decision task. Participants were informed that they would be shown two items in succession, and they needed to respond (as quickly and accurately as possible) whether the second item is a word in the English language. They responded using a computer mouse (i.e left button click for word, right button click for nonword).

Each trial began with a fixation cross displayed for 800ms. Next, a prime was displayed for either 200ms or 700ms. The prime was followed by a target word which remained on the screen until the participant responded. Accuracy and reaction times were recorded for each trial. Reaction times were calculated from the time the second stimulus was displayed until the participant responded using the mouse click. Feedback was given if the participant responded too slowly (response times slower than 800ms). There was a total of 240 trials. See *Figure 1* for a typical trial design.

Figure 1: **Illustration of typical trial structure**

Results

Accuracy analyses

Prior to main analyses, data was cleaned. Participants were excluded from the accuracy analyses due to low accuracy (less than 80% correct, N=11), inability to understand task (responses by chance, 50% correct, N=7) and incompletion of the study (N=1).

Preliminary analyses: Lexicality & Relatedness effects on Accuracy

In the first step of the analyses we looked at lexicality and relatedness effects. An independent samples t-test was used to compare accuracy for words and nonwords. Participants were significantly (t (486) =11.131, $p<.001$) more accurate responding to words (M = .93, SD = .08) than nonwords (M =.81, SD=.14). Next, we examined the relatedness effect by conducting a paired samples t-test. for related and unrelated word pairs. Participants responded more accurately to related pairs ($M=.94$, $SD=.07$) than unrelated pairs ($M=.81$, $SD=.08$), (t (119) = 2.70, p=.008).

Main analyses: Effects of Thematic Type on Accuracy

Table 3 shows descriptive statistics of the difference score (i.e. facilitation) of accuracy between the four Thematic Types. In the next step, we computed a difference score of accuracy by subtracting accuracy for unrelated word pairs from accuracy for related word pairs. Given the differences in associative relatedness and potential for interaction across the four Thematic Types, we assessed possible influence of these measures of relatedness on priming effects. Thus, we analyzed correlations between the difference score of accuracy and these two measures of relatedness. We found no significant (p=.774, p=.272 respectively) correlation between priming

effects and either of the two measures. Thus, associative relatedness and potential for interaction were not included in further analyses.

Table 3

Mean of relatedness between four Thematic Types on accuracy

	Argument	Attributive	Coordinate	Locative
Related	.95 (.05)	.93 (.09)	.95 (.04)	.91 (.08)
Unrelated	.94 (.05)	.91 (.10)	.93 (.07)	.90 (.09)

Notes: Mean and Standard Deviation

In the third step of analysis, we conducted a one-way ANOVA with the accuracy facilitation as a dependent and Thematic Type (Argument, Attributive, Coordinate, Locative) as a factor. Our analyses confirmed that there were no significant differences between the four Thematic Types (p=.845). *Figure 2* shows facilitation in accuracy across the four Thematic Type.

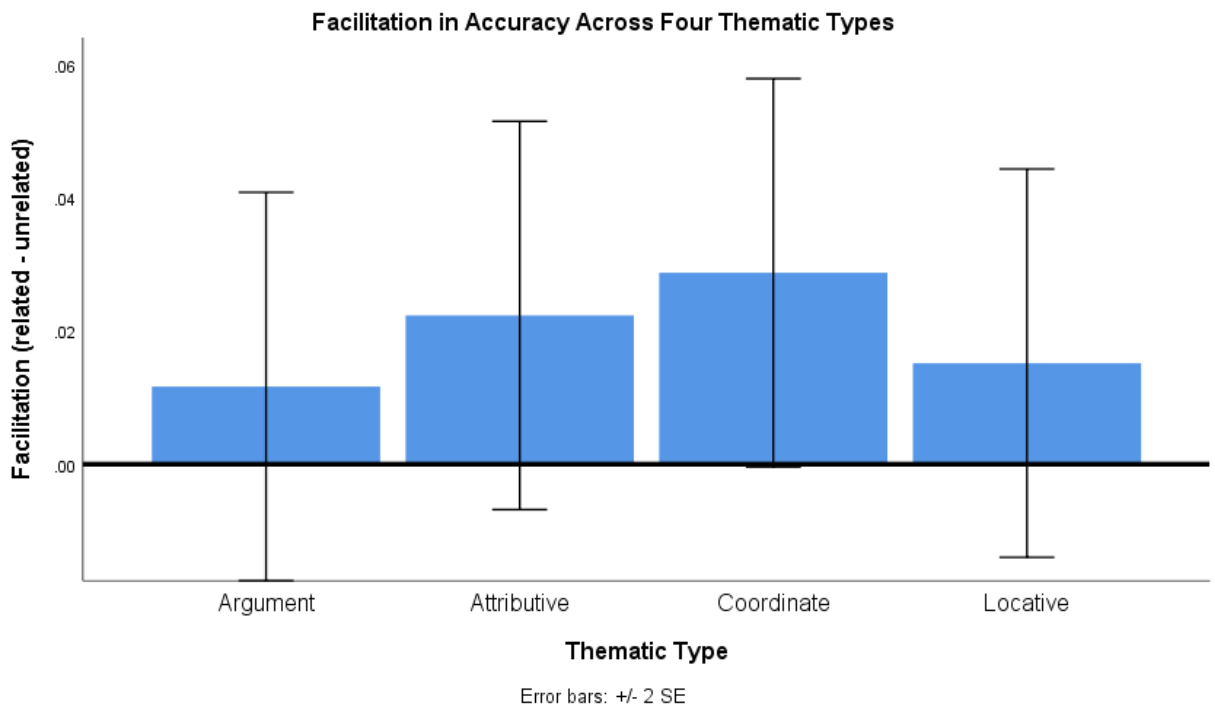

Figure 2: facilitation on accuracy across four Thematic Types

Reaction Times analyses

In analyses of reaction times, trials were only analyzed if participants responded correctly. Individual trials were also excluded if response latencies were below 150ms or above 1500ms as that meant participants were not adequately engaged in the trials of the experiment. This excluded 1,509 trials from analysis (~10% of trials).

Preliminary: Lexicality & Relatedness effects on Reaction times

In the first step of reaction time analyses we looked at lexicality and relatedness effects. An independent samples t-test was used to compare reaction times for words and nonwords. Participants responded significantly faster to words than nonwords (t (365) = 10.21, p < .01).

Reaction times had a mean of 528ms (*SD* = 58.45) for words and 602ms (*SD* = 77.79) for nonwords. Next, we analyzed the relatedness effect by comparing reaction times for related and unrelated word pairs in a paired samples t-test. Participants responded significantly ($p<.01$) quicker to related pairs *(M=522, SD=55.00*) than to unrelated pairs *(M=534, SD=61.53),* (t (119) = 2.70, $p=.008$).

Main analyses: Effects of Thematic Type on Reaction times

Table 4 shows descriptive statistics of the difference score (i.e. facilitation) of reaction times between the four Thematic Types**.** In the next step, we calculated a difference score of reaction times between related and unrelated word pairs. We further investigated the correlations between the difference score of reaction times and associative relatedness and interaction potential. difference score and checked for possible correlations among associative relatedness and interaction. Again, there was no significant correlation between the difference score and the associative relatedness or potential for interaction ($p=.097$, $p=.831$). Therefore, these measures were not included in further analyses of reaction times.

Table 4

Mean of relatedness between four Thematic Types on reaction time

	Argument	Attributive	Coordinate	Locative
Related	511 (51.19)	539 (62.01)	513 (51.98)	525 (52.31)
Unrelated	513 (48.01)	540 (57.53)	530 (65.78)	554 (68.36)

Notes: Mean and Standard Deviation

In the third step, we conducted a one-way ANOVA with facilitation of reaction time as the dependent and Thematic Type as the factor. Differences in priming effects across Thematic Types did not reach significance, however, there was a marginally significant effect (F (3,119) = 2.23, p=.08, η =.06) showing a tendency that was further examined by using LSD post-hoc comparisons. The analysis showed significant differences between locative and attributive (Mdiff=27.71, p=.03) and locative and argument (Mdiff=26.90, p=.035) Thematic Types. *Figure 3* shows reaction time facilitation by Thematic Type. Further, we computed a one-samples t-test for each of the Thematic Types and found that only coordinate and locative Thematic Types were significantly different than zero (t (29) =2.12, p=.043), and locative (t (29) =3.478, p=.002).

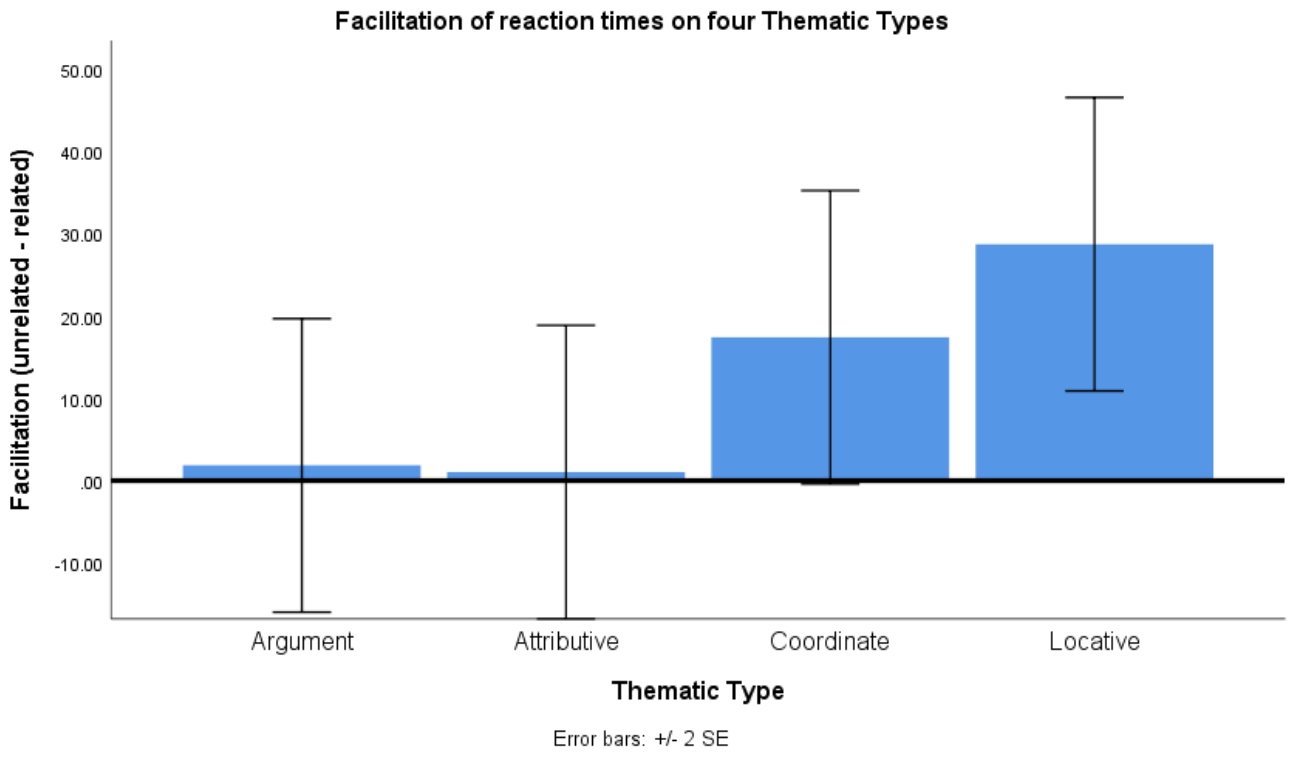

Figure 3: facilitation on reaction time across four Thematic Types

Discussion

The goal of the present study was to investigate how difference types of thematic relations affect cognitive processing in a lexical decision task. We used production norms by Jouravlev and McRae (2015) to select pairs of thematically related words of four Thematic Types: argument, attributive, coordinate, and locative.

We found significant priming effects of thematic relation on both accuracy and reaction times. For decades the dominant view was that thematic relations influence the cognitive processing only in childhood (Vygotsky, 1962; Inhelder & Piaget, 1964; Lin & Murphy, 2001). The present study suggests an important piece of evidence as it yields further support to a growing body of literature suggesting the importance of thematic relations in adulthood.

One of the goals of this study was to test the assumption of the importance of the potential for the interaction between the thematically related items. As Estes, Golonka & Jones (2011) suggested thematically related objects are those that not only co-occur but also have features that allow them to interact with each other. However, we found no support for this hypothesis. We found no significant correlation between the estimates of potential for interaction and priming effects. It is interesting that in our sample, we also did not find the effect of associative strength. This might be the consequence of small variability on these two measures (interaction and associative strength) in our sample, which may have resulted from our selection criteria discussed in Study 1.

The second goal of the study was to examine differences in priming between the four types of thematic relatedness: argument, attributive, coordinate, and locative. Although thematically related words were processed more accurately than unrelated ones, we did not find significant

effect of the Thematic Type on accuracy. The lack of the Thematic Type on accuracy might have resulted from a commonly reported trade-off effect between accuracy and reaction times.

In addition to the overall effect of relatedness, we also found an effect of the Thematic Type in the analyses of the reaction times. The Locative type of thematic relatedness showed stronger priming effect than Argument and Attributive, while none of the three types were different from the Coordinate thematic relatedness. Follow-up analyses have shown that only Locative and Coordinate types of thematic relatedness were strong enough to show the facilitation effect on reaction times, when their effects were analyzed separately.

Note that the neither Locative nor Coordinate types of thematic relatedness, the types we found to have strongest priming effects, are based on anything but frequent co-occurrence of items. A coordinate relation is based on two objects being a part of the same event, without a need for interaction (BEER - CHIPS). Similarly, locative relations are shared by an item and its typical location (DOCTOR - HOSPITAL). This gives further support to the account of thematic relatedness that assumes that a necessary and sufficient condition for items to be thematically related is that items frequently co-occur. In other words, there was no support for the need for interaction between objects as was previously hypothesized.

The reason for the lack of the priming effect for attributive (BAKER - APPRON) and argument (BEAR - FISH) relations is still unclear. While this finding may potentially show that attributive relations as part-whole relations, may be weaker than object-object relations, it is surprising that we found no priming for the argument relations. Argument relations are those that in addition to co-occurrence assume that one of the objects performs an action that changes the state of the other object, or, in other words, in addition to co-occurrence an interaction between the items is also assumed. This is the type of the thematic relatedness that is commonly used in

studies and it is the one for which we might expect strongest priming effect. Note that the lack of the priming could also be due to the significant individual variation, and thus it could be that we had not enough power to detect the priming effects of smaller intensity. Further investigation would be needed to offer a fuller understanding of the complexity of the thematic relatedness effects.

Although the number of findings suggesting the importance of thematic relations across the life span is rapidly growing (Lin & Murphy, 2001; Mirman & Graziano, 2012; Savic, Savic, & Kovic, 2017), there is still no consensus on the nature of this important type of semantic relatedness. Here we presented a study that compared the effects of different types of thematic relatedness on cognitive processing. We found evidence supporting the assumption that thematic relatedness relies on reliable co-occurrence between items. However, there was no evidence for the role of the interaction in defining thematic relations. The studies presented here show a potentially fruitful approach in further investigation of the complexity of the thematic relations.

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